

ON THE APPARENT LACK OF Be X-RAY BINARIES WITH BLACK HOLES

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Abstract

In the Galaxy there are 72 Be X-ray binaries known to-date. Out of those, 48 host a neutron star, and for the reminder the nature of a companion is not known. None, so far, is known to host a black hole. This disparity is referred to as a missing Be – black hole X-ray binary problem. The stellar population synthesis calculations following the formation of Be X-ray binaries (Belczyński & Ziółkowski 2009) predict that the ratio of the binaries with neutron stars to the ones with black holes is rather high $F_{\text{NS/BH}} \sim 30 - 50$. The ratio is a natural outcome of (1) the stellar initial mass function that provides more neutron stars than black holes and (2) common envelope evolution (i.e. a major mechanism involved in the formation of interacting binaries) that naturally selects progenitors of Be X-ray binaries with neutron stars (comparable mass binaries have more likely survival probabilities) against ones with black holes (much more likely common envelope mergers). A comparison of this ratio with the number of confirmed Be – neutron star X-ray binaries (48) indicates that the expected number of Be – black hole X-ray binaries is of the order of only $\sim 0 - 2$. This is entirely consistent with the observed Galactic sample. Therefore, there is no problem of the missing Be+BH X-ray binaries for the Galaxy

In the Magellanic Clouds there are 98 Be X-ray binaries known to-date. Out of those, 63 host a neutron star. Again, none hosts a black hole. The stellar population synthesis calculations carried out specifically for the Magellanic Clouds (Ziółkowski & Belczyński 2010) predict that the ratio of the Be X-ray binaries with neutron stars to the ones with black holes is only $F_{\text{NS/BH}} \sim 10$. This value is rather too low, as it implies the expected number of Be+BH X-ray binaries of the order of ~ 6 , while none is observed. We believe, that to remove the discrepancy, one has to take into account a different history of the star formation rate in the Magellanic Clouds, with the respect to the Galaxy. New stellar population synthesis calculations are currently being carried out.

An updated (as of November 2011) list of all 170 Be X-ray binaries known presently in the Galaxy and in the Magellanic Clouds is included.

1 Introduction

High mass X-ray binaries host a compact object (a neutron star or a black hole) and a massive star. The major subclass of high mass X-ray binaries consists of a Be star and a compact object and they are referred to as Be X-ray binaries (Be XRBs). The Be stars are massive, generally main sequence, stars of spectral types A0-O8 with Balmer emission lines (Negueruela 1998). The Be XRBs are found with rather wide (orbital periods in the range of $\sim 10 - 350$ days) and frequently eccentric orbits and a compact object accretes from the wind of a Be star (even massive Be stars are within their Roche lobes for these wide orbits). At present, 170 Be XRBs are known in the Galaxy and in the Magellanic Clouds, and in 111 of them, the compact object was confirmed to be a neutron star (NS) by the presence of the X-ray pulsations. In the remaining cases, whenever we have information concerning the nature of the compact component (such as an X-ray spectrum), it also indicates a NS. Although one cannot exclude that a few of these systems contain white dwarfs or black holes, it is fair to state that majority of them contain NSs as compact components. We know, at present, 60 black hole candidate systems in the Galaxy and in the Magellanic Clouds (among them 22 confirmed BH systems; e.g., Remillard & McClintock 2006; Ziółkowski 2008). However, not a single black hole binary containing a Be type com-

ponent has been found so far. This disparity, 111 Be XRBs with NSs versus not a single one with a BH, seems indeed striking.

The X-ray emission from Be XRBs (with a few exceptions) is of a distinctly transient nature with rather short active phases separated by much longer quiescent intervals (a flaring behavior). There are two types of flares, which are classified as Type I outbursts (smaller and regularly repeating) and Type II outbursts (larger and irregular; Negueruela & Okazaki 2001, Negueruela et al. 2001). Type I bursts are observed in systems with highly eccentric orbits. They occur close to periastron passages of a NS. They are repeating at intervals $\sim P_{\text{orb}}$. Type II bursts may occur at any orbital phase. They are correlated with the disruption of the excretion disc around Be star (as observed in $H\alpha$ line). They repeat on time scale of the dynamical evolution of the excretion disc (\sim few to few tens of years). This recurrence time scale is generally much longer than the orbital period (Negueruela et al. 2001).

Be XRBs systems are known to contain two discs: excretion disc around Be star and accretion disc around neutron star. Both discs are temporary: excretion disc disperses and refills on time scales \sim few to few tens of years (dynamical evolution of the disc, formerly known as the “activity of a Be star” (Negueruela et al. 2001)), while the accretion disc disperses and refills on time scales \sim weeks to months (which is related to the orbital motion on an eccentric orbit and, on some occasions, also to the major instabilities of the other disc). The accretion disc might be absent over a longer period of time (\sim years), if the other disc is very weak or absent. The X-ray emission of Be XRBs binaries is controlled by the centrifugal gate mechanism, which, in turn, is operated both by the periastron passages (Type I bursts) and by the dynamical evolution of the excretion disc (both types of bursts). This mechanism explains the transient nature of the X-ray emission (see Ziółkowski 2002 and references therein).

The more detailed description of the properties of Be XRBs systems is given, e.g. in Negueruela et al. 2001, Ziółkowski 2002, Belczyński & Ziółkowski 2009 and references therein.

The list of all presently known Be XRBs in the Galaxy is given in Table 1, and the list of those known in the Magellanic Clouds is given in Table 2.

In further discussion, I will present the recent stellar population synthesis (SPS) calculations (Belczyński & Ziółkowski 2009, Ziółkowski & Belczyński 2010) aimed at the understanding of the origins of the apparent disparity of the number of known Be XRBs with neutron stars (NSs) (111) as compared to no known Be XRBs with black holes (BHs) in the Galaxy and in the

Magellanic Clouds. This disparity is referred to as a missing Be – black hole X-ray binary problem.

2 SPS Calculations

2.1 SPS Code

We evolve a population of massive binaries using **StarTrack** stellar population synthesis code (Belczyński, Kalogera & Bulik 2002 and Belczyński et al. 2008). We adopt a steep initial mass function (IMF) for massive stars with a power-law exponent of -2.7 (Kroupa & Weidner 2003). We adopt solar metallicity ($Z = 0.02$) for galactic binaries and low metallicity ($Z = 0.008$) for Magellanic Clouds binaries. Roche lobe overflow is treated in a non-conservative way (with 50% mass loss from a given binary; e.g. Meurs & van den Heuvel 1989) while the CE phase is treated via energy balance with fully efficient transfer of orbital energy into dispersal of an envelope (e.g. $\alpha \times \lambda = 1.0$). The results are calibrated in such a way that the Galactic star formation rate is at the level of $3.5 \text{ M}_{\odot}/\text{yr}$ and is constant through the last 10 Gyr (e.g. O’Shaughnessy et al. 2008). At the present Galactic disk age ($t = 10 \text{ Gyr}$) we perform a time slice and extract Be X-ray binaries using classification criteria defined in the following section.

2.2 Definition of a Be XRB for the purpose of SPS calculations

During our SPS calculations, we consider any system a Be X-ray binary if: (1) it hosts either a NS or a BH accretor; (2) donor is a main sequence star (burning H in its core); (3) donor mass is higher than 3 M_{\odot} (O/B star); (4) orbital period is in the range $10 \leq P_{\text{orb}} \leq 300 \text{ day}$; and (5) only a fraction $F_{\text{Be}} = 0.25$ of the above systems are designated as hosting a Be star and not a regular O/B star.

The last condition is based on the observations indicating that the fraction of Be stars among all B stars is $1/5$ to $1/3$ (e.g., Ziółkowski 2002; McSwain & Gies 2005).

Our set of conditions means that we assume that whenever donor is a Be star then the accretion is always efficient, independently of the size of the binary orbit (as is, in fact, observed in Be/NS XRBs).

2.3 SPS Models

We carried out the calculations for three models of SPS. In model A, it was assumed that the binary system will survive the situation when the donor star will overflow its Roche lobe while crossing the Hertzsprung gap. With the present state of knowledge, it seems doubtful, as this would rather lead to a merger of both components (Taam & Sandquist 2000, Ivanova & Taam 2004). However, since model A used to be a standard in the past, we still carried out the calculations for this case. More realistic seem to be models B and C, which assume that overflowing by a donor its Roche lobe while crossing the Hertzsprung gap, leads to a merger and removal of the binary from the statistics. The difference between the models B and C concerns the natal kicks compact objects receive at birth. Model B assumes for NSs the kicks drawn from the radio pulsar birth velocity distribution derived by Hobbs et al. (2005; a Maxwellian with $\sigma = 265$ km/s). However, there are some indications that natal kicks neutron stars receive are smaller for stars in binaries as compared to single stars (e.g. Podsiadlowski et al. 2004). Therefore, model C assumes a Maxwellian distribution with $\sigma = 133$ km/s.

3 Results for the Galaxy

For model A the expected ratio of Be-X binaries with NSs to the ones with BHs, $F_{\text{NS/BH}}$ was found to be ~ 7 . For, more physically realistic, models B and C, this ratio was found to be, respectively, 27 and 54. This relatively high ratio (for models B and C) is a natural outcome of (1) the stellar initial mass function that provides more neutron stars than black holes and (2) common envelope evolution (i.e. a major mechanism involved in the formation of interacting binaries) that naturally selects progenitors of Be X-ray binaries with neutron stars (comparable mass binaries have more likely survival probabilities) against ones with black holes (much more likely common envelope mergers).

The expected distributions of orbital periods and eccentricities for Be/NS and Be/BH binaries for model C are shown in Fig. 1. For comparison, the observed orbital periods distribution for 27 galactic Be/NS binaries is shown in Fig. 2.

More detailed description of the results is given in Belczyński & Ziółkowski (2009).

Now, let me remind that in the Galaxy there are 72 Be X-ray binaries known to-date. Out of those, 48 host a confirmed neutron star. None, so far,

is known to host a black hole. The stellar population synthesis calculations presented above predict that the ratio of the binaries with neutron stars to the ones with black holes should be high $F_{\text{NS/BH}} \sim 30 - 50$. A comparison of this ratio with the number of confirmed Be – neutron star X-ray binaries (48) indicates that the expected number of Be – black hole X-ray binaries is of the order of only $\sim 0 - 2$. This is entirely consistent with the observed Galactic sample. Therefore, there is no problem of the missing Be+BH X-Ray Binaries for the Galaxy.

4 Results for the Magellanic Clouds

In the Magellanic Clouds there are 98 Be X-ray binaries known to-date. Out of those, 63 host a confirmed neutron star. Again, none hosts a black hole. The preliminary stellar population synthesis calculations carried out specifically for the Magellanic Clouds (Ziółkowski & Belczyński 2010) predict that the ratio of the Be X-ray binaries with neutron stars to the ones with black holes is only $F_{\text{NS/BH}} \sim 10$ (for model C). This value is rather too low, as it implies the expected number of Be+BH X-ray binaries of the order of ~ 6 , while none is observed. Obviously, in contrast to the Galaxy, there is a problem of the missing Be+BH X-Ray Binaries for the Magellanic Clouds. We believe, that to remove the discrepancy, one has to take into account a different history of the star formation rate in the Magellanic Clouds, with the respect to the Galaxy. During our preliminary calculations, we used the galactic scenario for the star formation rate. However, Magellanic Clouds are in many ways very different from the Galaxy when comparing the population of XRBs. Let us compare the numbers for three classes of XRBs:

- (1) Be XRBs: 72 in the Galaxy vs 98 in the Magellanic Clouds
- (2) other High Mass XRBs: 46 vs 11
- (3) Low Mass XRBs: 197 vs 2

It is obvious that formation of stars in Magellanic Clouds had to proceed in a completely different way from that in the Galaxy. We are currently carrying out the new stellar population synthesis calculations trying to take into account this fact.

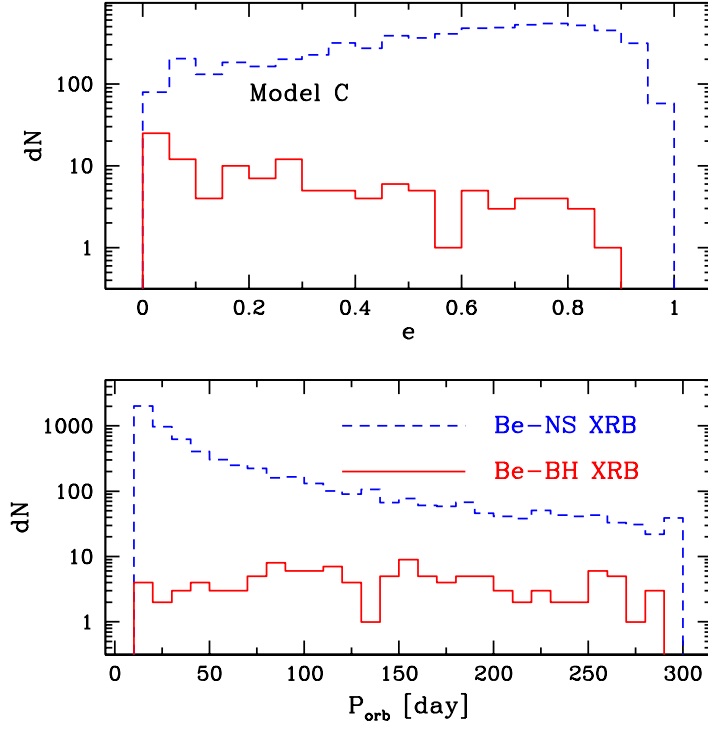


Figure 1: Expected orbital period and eccentricity distributions for Be/NS (broken line) and Be/BH (continuous line) binaries for model C of stellar population synthesis (see the text).

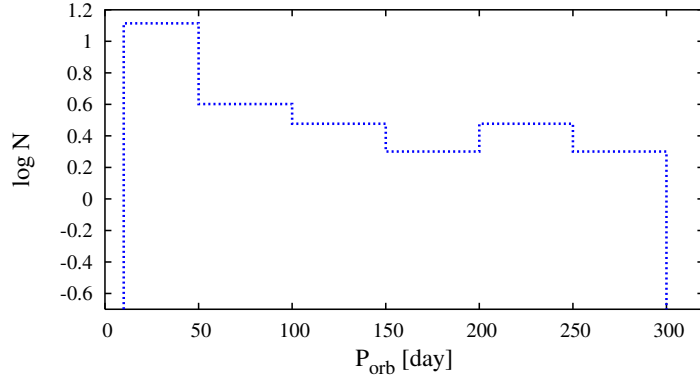


Figure 2: Observed orbital period distribution for 27 galactic Be/NS binaries.

Tab. 1 – Galactic Be X-ray Binaries^a

Name	P_{orb} [d]	P_{spin} [s]	e	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
2S 0053+604	203.59		0.26	3.9×10^{34}	B0.5 Ve	1
4U 0115+634	24.3	3.61	0.34	3.0×10^{37}	B0.2 Ve	
IGR J01363+6610	160			1.3×10^{35}	B1 Ve	
RX J0146.9+6121		1404.2		3.5×10^{35}	B1 Ve	
IGR J01583+6713					Be	
1E 0236.6+6100	26.496		0.55	2.0×10^{34}	B0 Ve	2
V 0332+53	34.25	4.4	0.37	$> 1.0 \times 10^{38}$	O8.5 Ve	
4U J0352+309	250.3	837.0	0.11	3.0×10^{35}	O9.5 IIIe - B0 Ve	
RX J0440.9+4431	155	202.5		3.0×10^{34}	B0.2 Ve	
EXO 051910+3737.7				1.3×10^{35}	B0 IVpe	
1A J0535+262	111.0	103.4	0.47	2.0×10^{37}	O9.7 IIIe	3
1H 0556+286					B5ne	
IGR J06074+2205					B0.5 Ve	
HESS J0632+057	~ 320				Be	
SAX J0635.2+0533	11.2	0.0338		$9 \div 35 \times 10^{33}$	B1 IIIe - B2 Ve	
XTE J0658-073		160.4		6.6×10^{36}	O9.7 Ve	4
3A J0726-260	34.5	103.2		2.8×10^{35}	O8-9 Ve	
1H 0739-529					B7 IV-Ve	
1H 0749-600					B8 IIIe	
RX J0812.4-3114	81.3	31.8851		1.1×10^{36}	B0.2 IVe	
GS 0834-430	105.8	12.3	0.12	1.1×10^{37}	B0-2 III-Ve	4
GRO J1008-57	247.5	93.5	0.66	2.9×10^{35}	B0e	
RX J1037.5-5647		862.0		4.5×10^{35}	B0 III-Ve	
1A 1118-615		407.68		5.0×10^{36}	O9.5 Ve	
IGR J11305-6256				1×10^{35}	B0.5 IIIe	
IGR J11435-6109	52.46	161.76			Be	4
2S 1145-619	187.5	292.4	> 0.5	7.4×10^{34}	B0.2 IIIe	
1H 1253-761					B7 Vne	
1H 1255-567					B5 Ve	
4U 1258-61	132.5	272.0	> 0.5	1.0×10^{36}	B0.7 Ve	
2RXP J130159.6-635806		704.0		5.0×10^{35}	Be ?	4
SAX J1324.4-6200		170.84		$\sim 10^{34}$	Be ?	

Tab. 1 – Galactic Be X-ray Binaries^a (continued)

Name	P_{orb} [d]	P_{spin} [s]	e	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
1WGA J1346.5-6255				6.6×10^{32}	B0.5 Ve	
2S 1417-624	42.12	17.6	0.446	8.0×10^{36}	B1 Ve	
SAX J1452.8-5949		437.4		8.7×10^{33}	Be ?	
XTE J1543-568	75.56	27.12	< 0.03	$> 1.0 \times 10^{37}$	Be ?	
2S 1553-542	30.6	9.26	< 0.03	7.0×10^{36}	Be ?	
IGR J15539-6142				3.3×10^{33}	B2-3 Vne	
IGR J16207-5129				1.3×10^{34}	B8 IIIe	
SWIFT J1626.6-5156		15.37			B0-2 Ve	5
AX J170006-4157		714.5		7.2×10^{34}	Be ?	
AX J1700.2-4220	44.12	54.22			Be ?	6
XTE J1716-379		670.46			Be ?	7
RX J1739.4-2942					Be ?	
RX J1744.7-2713				1.8×10^{32}	B0.5 V-IIIe	
AX J1749.1-2733	185.5	66		3×10^{36}	Be ?	4,8
AX J1749.2-2725		220.38		2.6×10^{35}	Be ?	
GRO J1750-27	29.8	4.45			Be ?	
1XMM J180816.8-191940				1.3×10^{33}	Be ?	
AX J1820.5-1434		152.26		9.0×10^{34}	O9.5 - B0 Ve	
XTE J1824-141		120.0			Be ?	
1XMM J183327.7-103523				$1.6 \div 7.5 \times 10^{32}$	B0.5 Ve	
1XMM J183328.7-102409				3.3×10^{32}	B1-1.5 IIIe	
GS J1843+00		29.5		3.0×10^{37}	B0-2 IV-Ve	
2S 1845-024	242.18	94.8	0.88	6.0×10^{36}	Be ?	
IGR J18483-0311	18.52	21.0526		7.8×10^{36}	Be ?	4,9
XTE J1858+034		221.0			Be ?	
XTE J1859+083	60.65	9.801			Be ?	10
4U 1901+03	22.58	2.763	0.036	1.1×10^{38}	Be ?	
XTE J1906+09	28.0 ?	89.17			Be ?	
IGR J19294+1816	117.2	12.44			Be ?	11
1H 1936+541					Be	
XTE J1946+274	169.2	15.8	0.33	5.4×10^{36}	B0-1 IV-Ve	
KS 1947+300	40.415	18.76	0.03	2.1×10^{37}	B0 Ve	

Tab. 1 – Galactic Be X-ray Binaries^a (continued)

Name	P_{orb} [d]	P_{spin} [s]	e	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
W63 X-1		36.0			Be ?	
EXO 2030+375	46.02	41.8	0.41	1.0×10^{38}	B0 Ve	
RX J2030.5+4751				1.7×10^{33}	B0.5 V-IIIe	
GRO J2058+42	55.03	198.0		2.0×10^{36}	O9.5-B0 IV-Ve	
SAX J2103.5+4545	12.68	358.61	~ 0.4	3.0×10^{36}	B0 Ve	
1H 2138+579		66.33		9.1×10^{35}	B0-2 IV-Ve	
1H 2202+501					Be	
SAX J2239.3+6116	262.6	1247.0		$\sim 2.3 \times 10^{36}$	B0 V - B2 IIIe	

^aNote that I have not included into the table the following systems: 1H 1249-637 (compact companion is probably a white dwarf, Liu et al. 2006); IGR J16318-4848 (B[e] optical component (not Be), Liu et al. 2006); 1H 1555-552 (Herbig Ae/Be optical component (not Be), Liu et al. 2006); PSR B1259 (non-accreting XRB, Tavani & Arons 1997)

^bMaximum X-ray luminosity

^cReferences for most of the systems are given in Belczyński & Ziółkowski 2009; Additional references are: (1) Corbet & Krimm 2010; (2) Tsygankov et al. 2011; (3) Falcone et al. 2011 (4) Bird et al. 2010; (5) Nespoli et al. 2011 (6) Markwardt et al. 2010; (7) Markwardt et al. 2009; (8) Zurita & Chaty 2008; (9) Sguera et al. 2007; (10) Corbet et al. 2009b; (11) Corbet & Krimm 2009.

Tab. 2 – Be X-ray Binaries in Magellanic Clouds^a

Name	P_{orb} [d]	P_{spin} [s]	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
RX J0032.9-7348			1.3×10^{37}	Be	1
RX J0045.6-7313			1.2×10^{35}	Be ?	1
RX J0047.3-7312	49.06	262.23	1.8×10^{36}	B0.5e	1,2,3,4,5
XMMU J004814.1-731003	22.5	25.55	2.1×10^{35}	B1.5e	1,2,4,5
AX J0048.2-7309			5.2×10^{35}	Be	1,6
RX J0048.5-7302			3.0×10^{35}	B1.5e	1,5,6
AX J0049-729	33.37	74.676	7.5×10^{36}	~B3 Ve	1,3,4
	642 ?				
RX J0049.2-7311	80.1	9.1321	3.3×10^{35}	B1-3 IV-Ve	1,4,5,7
CXOU J004929.7-731058		894.36	9.3×10^{34}	B1e	1,5,8
RX J0049.5-7310	91.5		4.1×10^{35}	Be	1,6
RX J0049.5-7331			5.1×10^{35}	Be	1,6
RX J0049.7-7323	391	746.24	7.7×10^{35}	O9.5-B0 III-Ve	1,2,3,4,7,8
2S J0050-727	44.92	7.7912	6×10^{37}	B1-1.5 IV-Ve	1,2,3,4,7
RX J0050.7-7316	116.6	317.26	1.8×10^{36}	B0.5e	1,2,3,5,8
RX J0050.7-7332			2.4×10^{34}	Be	1,6
RX J0050.9-7310			4.5×10^{35}	B0.5e	1,5
2E 0051.1-7304			1.6×10^{35}	B0e	1,6
RX J0051.3-7216	88.3	91.12	2.9×10^{37}	B0.5e	1,3,4,5,7,9
	115 ?				
RX J0051.3-7250			3.6×10^{34}	Be	1,6
IGR J00515-7328			1.1×10^{36}	Be	10,11
RX J0051.8-7231	28.51	8.899	1.4×10^{36}	O9.5-B0 IV-Ve	1,3,4,7,8
RX J0051.8-7310	67.88	172.4	5.6×10^{36}	B0e	1,3,4,5,7
RX J0051.9-7255			6.0×10^{34}	Be	1,6
XTE J0052-723	23.9 ?	4.78	7.2×10^{37}	B0-1 Ve	1,7
XTE J0052-725	171	82.46	3.4×10^{36}	B1-3e	1,3,4,5,7
RX J0052.1-7319	74.51	15.3	1.3×10^{37}	O9.5-B0 III-Ve	1,3,4,7
XMMU J005252.1-721715	45.9	326.79	1×10^{37}	Be	1,2,4,8,12
RX J0052.9-7158	68.54	164.7	2.0×10^{37}	B0-1 III-Ve	1,3,7,13
H 0053-739	18.58	2.374	4.7×10^{38}	O9.5 III-Ve	1,3,4,14
CXOU J005323.8-722715	143.1 ?	139.136	1.18×10^{35}	B0.5e	1,2,3,4,5,7

Tab. 2 – Be X-ray Binaries in Magellanic Clouds^a (continued)

Name	P_{orb} [d]	P_{spin} [s]	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
1WGA J0053.8-7226	136.4	46.63	7.4×10^{36}	O9.5-B1 IV-Ve	1,3,4,7
XMMU J005403.8-722632		341.87	1.5×10^{35}	Be ?	1,2
2E0054.4-7237	197	140.1	4.0×10^{34}	B1 Ve	1,3,4
CXOU J005446.3-722523		4693	9×10^{32}	B0-1 Ve	8,15
RX J0054.5-7228			1.5×10^{36}	Be	1,6
AX J0054.8-7244	272	497.5	5.5×10^{35}	B1 III-Ve	1,2,3,4,7
XTE J0055-724	62.1	58.858	4.3×10^{37}	O9 Ve	1,2,3,4,7
XTE J0055-727	17.95	18.3814	2.6×10^{37}	B0-2 Ve	1,2,4,6,16
XMMU J005517.9-723853	412	701.7	4×10^{35}	O9.5 Ve	1,3,4,7
XMMU J005535.2-722906	135.3 ?	644.55	4.9×10^{35}	B0-0.5 III-Ve	1,2,4
RX J0055.4-7210	598 ?	34.08	1.1×10^{35}	B2-3 IV-Ve	1,3,4,17
XMMU J005615.2-723754			4.9×10^{34}	Be	1,6
CXOU J005736.2-721934	152.4	564.83	1.2×10^{36}	B0-2 IV-Ve	1,3,4,6,7
	95.3 ?				
AX J0057.4-7325	21.95	101.45	1.2×10^{36}	B3-5 Ib-IIe ?	1,3,4,7
RX J0057.8-7207		152.10	4.3×10^{35}	B1-2.5 III-Ve	1,3,7
RX J0057.8-7202	126.4	281.1	1.6×10^{36}	B0-2 III-Ve	1,3,4,7
RX J0057.9-7156			5.7×10^{34}	Be	1,6
RX J0058.2-7231	59.77	291.327	2.1×10^{35}	B2-3 Ve	1,2,4
RX J0059.2-7138	82.37	2.7632	5.0×10^{37}	B1-1.5 II-IIIe	1,3,4,7
XMMU J005929.0-723703	224	202.52	4.5×10^{36}	B0-5 IIIe	1,2,4
RX J0059.3-7223	71.98	200.50	3.2×10^{35}	B0-1 Ve	1,2,3,4,7
XMMU J010030.2-722035			2.6×10^{34}	Be	1,6
RX J0101.0-7206	344 ?	304.49	1.3×10^{36}	B0-2 III-Ve	1,3,4,7,18
RX J0101.3-7211	74.96	452.2	7.3×10^{35}	B0.5-2 IV-Ve	1,3,4,7
RX J0101.6-7204			3.8×10^{35}	Be	1,6
AX J0101.8-7223			2.2×10^{35}	Be	1,6
CXOU J010206.6-714115	101.94 ?	966.97	6.0×10^{35}	B0-0.5 III-Ve	1,2,4,19
	267.38 ?				
RX J0103-722	94.4	341.87	1.5×10^{36}	B0.5 IV-Ve	1,2,3,4,7
XTE J0103-728	110.0	6.8482	3.8×10^{37}	O9.5-B0 IV-Ve	1,3,4,7
	24.82 ?				

Tab. 2 – Be X-ray Binaries in Magellanic Clouds^a (continued)

Name	P_{orb} [d]	P_{spin} [s]	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
1H 0103-762			4.3×10^{35}	Be	1,6
RX J0103.6-7201	26.16 ?	1323.2	6.4×10^{36}	B0 III-Ve	1,3,6
RX J0104.1-7243			3.8×10^{34}	Be	1,6
RX J0104.5-7221			4.8×10^{34}	Be	1,6
AX J0105-722	11.09	3.343	1.5×10^{35}	B1-2 III-Ve	1,3,4,6
IGR J01054-7253	36.3	11.483		Be	20,21,22
RX J0105.9-7203		726	1.6×10^{35}	B0.5-3e	1,4,23
RX J0106.2-7205			5×10^{34}	B2-5 III-Ve	1,6
CXOU J010712.6-723533	110.6	65.95	3.0×10^{36}	B1-1.5 II-IIIe	1,2,3
AX J0107.2-7234			2.3×10^{34}	Be	6
XTE J00111.2-7317	90.5	31.0294	2.0×10^{38}	O9.5-B1 Ve	1,3,4,6
RX J00117.6-7330		22.07	1.2×10^{38}	O9.5-B0 III-Ve	1,3
XTE J00119-731		2.1652	6.3×10^{36}	Be ?	1,6,7
RX J00119.6-7330			1.5×10^{34}	Be	1,6
SMC SXP7.92		7.92		Be	24
XTE SMC 95	283 ?	95.2	2×10^{37}	Be ?	1,7
	71.3 ?				
XTE SMC 144	59.38	144.1		Be ?	1,7
SMC SXP707	37.15	707.464	1.4×10^{35}	Be ?	25
SMC SXP723		723	$> 3 \times 10^{37}$	Be ?	26
RX J0209.6-7427	40 ?		1.0×10^{38}	B0-1.5 IV-Ve	6,27
Swift J045106.8-694803	21.64	187		Be ?	28
IGR J05007-7047	30.77		4.5×10^{36}	B2 IIIe	29,30,31
RX J0501.6-7034			7×10^{34}	B0 Ve	1,6
RX J0502.9-6626		4.0635	4×10^{37}	B0 Ve	1,6
Swift J0513.4-6547		27.28		Be ?	32
RX J0516.0-6916			5×10^{35}	B1 Ve	1,6,33
XMMU J052016.0-692505			1×10^{38}	B0-3e	1,34
RX J0520.5-6932	24.4		8×10^{38}	O9 Ve	1
RX J0529.8-6556		69.5	2×10^{36}	B0.5 Ve	1
RX J0530.1-6551		271.97	3.9×10^{35}	Be ?	1,35,36
EXO 053109-6609.2	25.4	13.7	1×10^{37}	B0.7 Ve	1,6

Tab. 2 – Be X-ray Binaries in Magellanic Clouds^a (continued)

Name	P_{orb} [d]	P_{spin} [s]	$L_{x,max}^b$ [erg/s]	Spectral type	Ref ^c
RX J0531.5-6518	241 ? 16.70 16.651	0.069	3×10^{35}	B2 Ve	1,37,38
RX J0532.4-6535			7×10^{34}	Be ?	1,37
RX J0535.0-6700			3×10^{35}	B0 Ve	1,37,38
1A 0535-668			1×10^{39}	B0.5 IIIe	1,6,39
XMMU J054134.7-682550	286 ?	61.601	2.0×10^{38}	Be ?	1,40
H 0544-665		96.08	1×10^{37}	B0 Ve	1,6
1SAX J0544.1-7100			2×10^{36}	B0 Ve	1,6
IGR J05414-6858			8×10^{36}	B1-2 IIIe	41,42

^aNote that I included into the table the system XMMU J052016.0-692505, although it is possible that it contains a white dwarf component instead of a NS (Kahabka et al. 2006; Raguzova 2008).

I did not include the system MAXI J1836-194, for which the initial optical spectroscopy suggested a Be optical component (Cenko et al. 2011), but this was not confirmed by later observations (Rau et al. 2011).

Excentricities are not given for Magellanic Clouds systems, as they are estimated for only two systems: IGR J01054-7253 ($e = 0.28$) and 1A 0535-668 ($e \geq 0.5$).

^bMaximum X-ray luminosity

^c (1) Raguzova 2007; (2) Haberl et al. 2008; (3) McBride et al. 2008; (4) Rajoelimanana et al. 2011a; (5) Antoniou et al. 2009; (6) Liu et al. 2006; (7) Galache et al. 2008; (8) Laycock et al. 2010; (9) Coe et al. 2005; (10) Sturm et al. (2011); (11) Kennea et al. 2011; (12) Coe et al. 2008; (13) Corbet et al. 2004; (14) Schmidtke et al. 2009a; (15) Schmidtke & Cowley 2010; (16) Coe & Udalski 2008; (17) Haberl & Eger 2008; (18) Sasaki et al. 2003; (19) Schmidtke et al. 2009b; (20) Coe et al. 2009; (21) Corbet et al. 2009a; (22) Townsend et al. 2009; (23) Eger & Haberl 2008; (24) Corbet et al. 2008; (25) Rajoelimanana et al. 2011b; (26) Townsend et al. 2011; (27) Kahabka & Hilker 2005; (28) Beardmore et al. 2009; (29) Masetti et al. 2006; (30) Bird et al. 2010; (31) La Parola et al. 2010; (32) Krimm et al. 2009; (33) Schmidtke et al. 1999; (34) Kahabka et al. 2006; (35) Haberl et al. 2003; (36) Shtykovskiy & Gilfanov 2005; (37) Haberl & Pietsch 1999;

(38) Negueruela & Coe 2002; (39) Alcock et al. 2001; (40) Markwardt et al. 2007; (41) Grebenev & Lutovinov 2010; (42) Rau et al. 2010.

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